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High Fidelity Radar Stimulation For Distributed Hardware-in-the-Loop Simulations

AMRDEC
STRENGTH THROUGH TECHNOLOGY

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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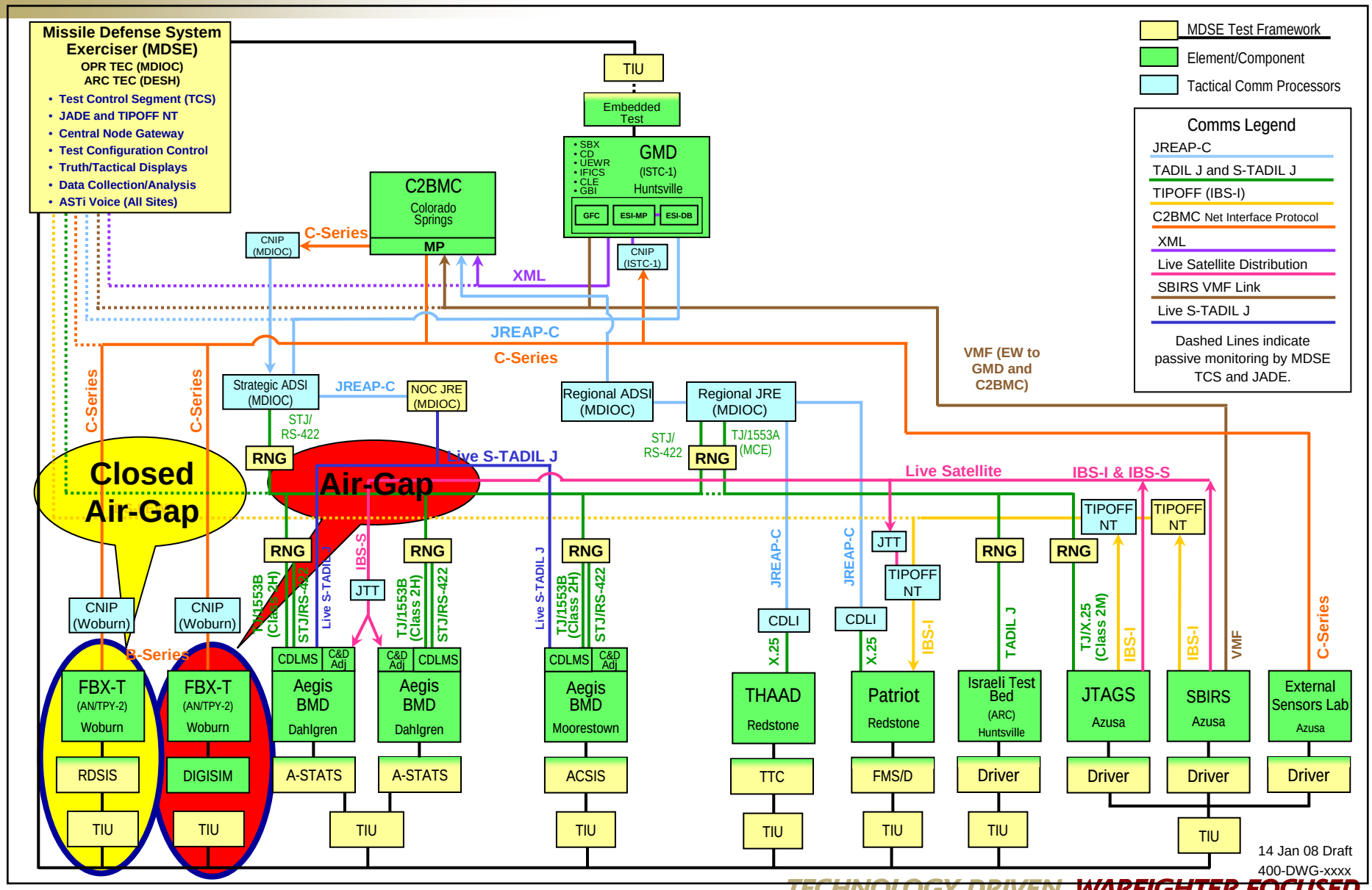
High Fidelity Stimulation Need

- **Models & Simulations (M&S) are critical in the today's development of the complex Ballistic Missile Defense System (BMDS)**
  - **Testing of the BMDS is costly**
  - **Geographic dispersion complicates test capability**
  - **A laboratory BMDS Ground Test (GT) network is enabled by M&S**

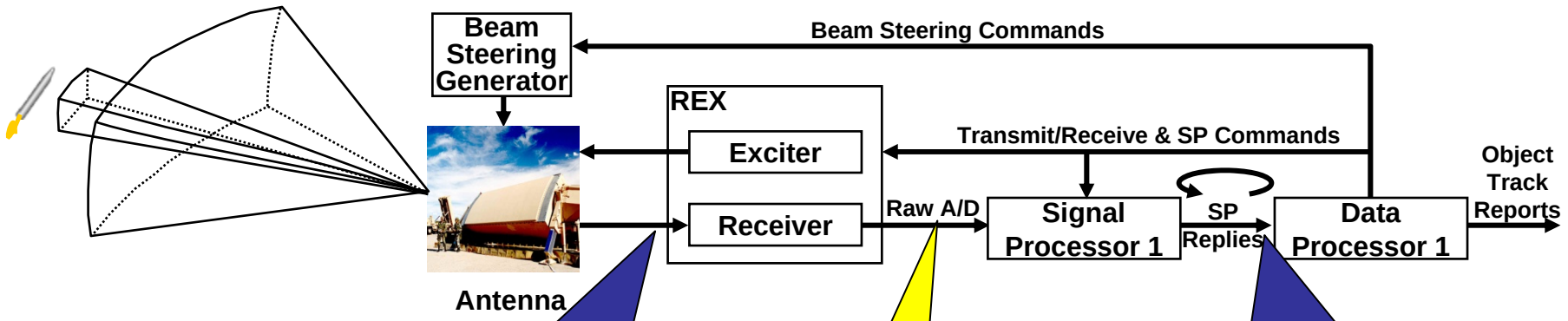
- **M&S are used to evaluate:**
  - **Design modifications to system architectures**
  - **Impacts of system hardware changes**
  - **Software capabilities prior to and after fielding**
  - **Evaluate system performance against emerging threats**
  - **Conduct pretest readiness and evaluations**

- **The BMDS AN/TPY-2 radar requires a high fidelity stimulator to adequately exercise critical software functions and processes such as advanced discrimination and distributed track processing**

DRAFT GTI-09 Objective Architecture



AN/TPY-2 Stimulation Injection Point Options



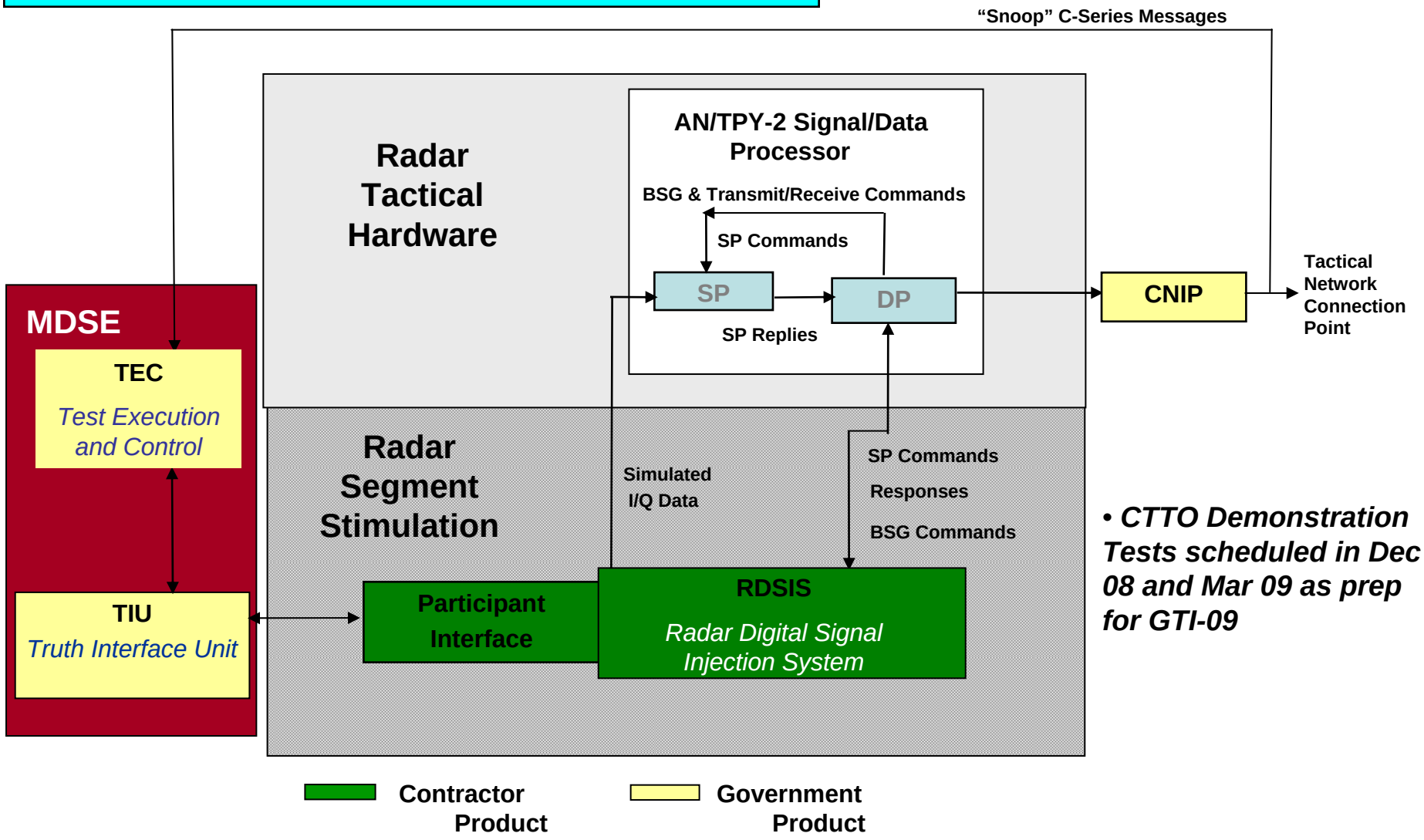
Low Fidelity Injection
- Analog Signal
- Limited Target Modeling
- System Verification/Checkout
- Limited Channel Stimulation

High Fidelity Injection
- Complex Target and Environment Signature Modeling
- Multiple Channel Stimulation
- Full System Software is Exercised – Detection and Track
- Performance Testing

Medium Fidelity Injection
- Limited Target and Environment Modeling
- Predetermined Detections with Track Processing Software Only

High Fidelity Stimulation Ground Test Architecture

AN/TPY-2 Closed Air-Gap (CAG) Configuration



- ***CTTO Demonstration Tests scheduled in Dec 08 and Mar 09 as prep for GTI-09***

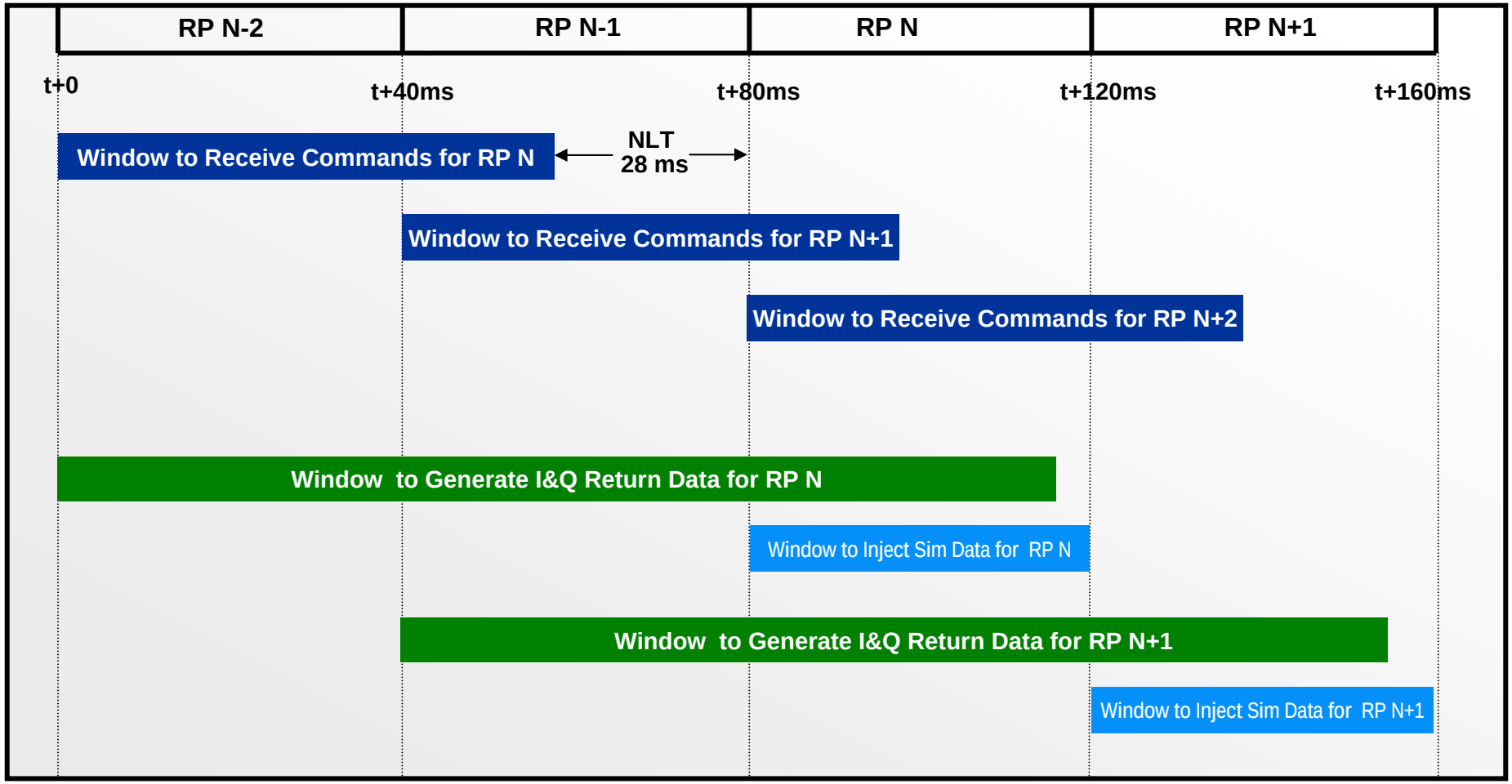
RDSIS System Performance Specification

- **RDSIS Objective - Develop a Tool that will Provide:**
  - **Real-Time Simulation of Radar Return Signals to Stimulate the BMDS Radar**
  - **A High Fidelity Driver for BMDS Ground Testing**
- **Radar Capabilities Supported by RDSIS:**
  - **One and Two Pass Configurations**
  - **Single Beam Search, Multi-Beam Search, Multi-Frequency Search, Multi-Beam-Multi- Frequency Search, Verification, Track, and Discrimination**
  - **Narrowband, Medium Band and Wideband Waveforms**
- **Natural Environment Modeling - Incorporate the effects of:**
  - **Atmospheric Absorption**
  - **Cloud and Precipitation Attenuation**
  - **Atmospheric Lens Loss and Refraction**

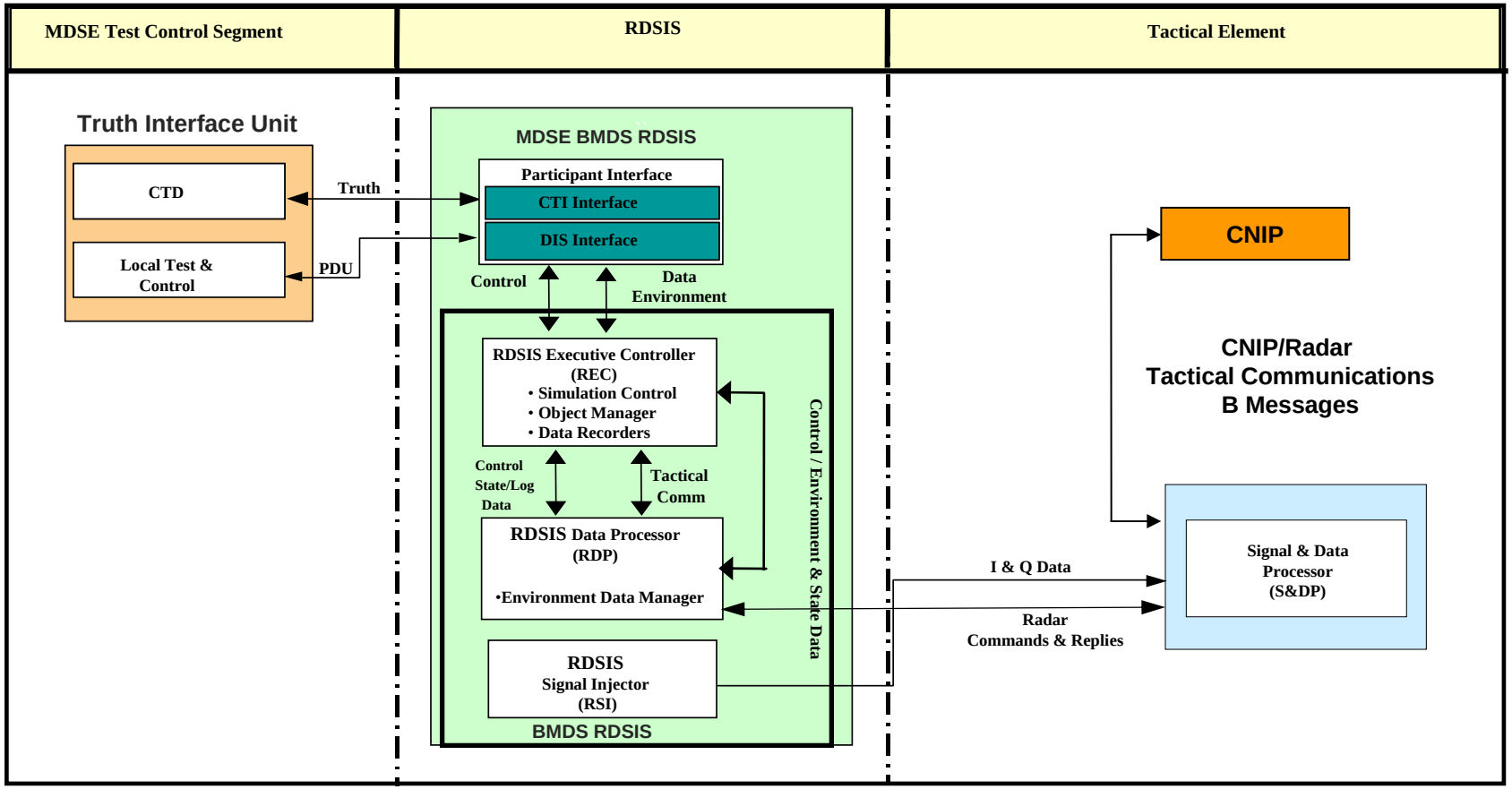
RDSIS System Performance Specification (cont.)

- Signal Characteristics
  - Generate real time I & Q for each Receiver Channel
  - Incorporate the Effects of AGC
  - Include Noise Injection
  - Model Sum and Difference Antenna Patterns (Mainbeam & Sidelobes)
  - Antenna Pattern Modeled for Transmit and Receive Antenna Weighting Functions
  - Include Effects of Outages and Amplitude and Phase Errors
- High Fidelity Modeling of I & Q Samples
  - Utilize Scattering Center Based Threat RCS Models
  - Utilize Threat Dynamics
    - Include Effects Due to Object Body Dynamics
    - Utilize Inputs Provided via 17 Column Trajectory Data Threat Dynamics

Example Data Generation Time Line



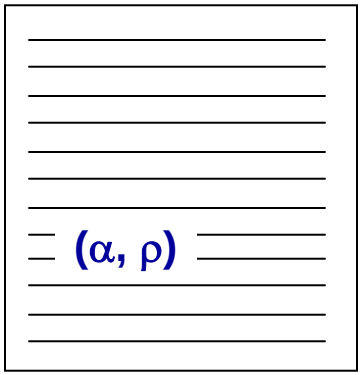
High Fidelity Stimulation Functional Breakout



Target Model Processing

N-Point Real-time Processing for MB & WB Waveforms

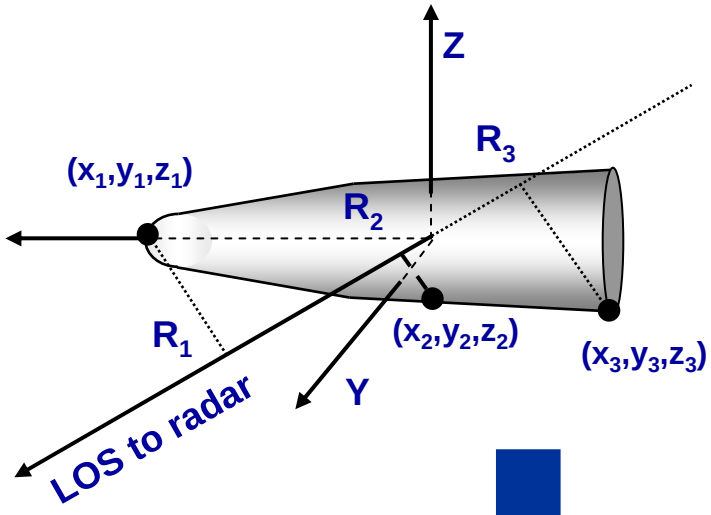
List of Scatterer Data



1. Extract scatterer data for particular aspect α, roll ρ and polarization

$\{((x_1,y_1,z_1);\sigma_1),$
$((x_2,y_2,z_2);\sigma_2),$
$((x_3,y_3,z_3);\sigma_2),...\}$

Scatterer data (3-D location + complex RCS)



2. Compute relative range and range rate for each scatterer, using body orientation and dynamics

$\{(R_1,R_1',\sigma_1), (R_2,R_2',\sigma_2),...\}$

For NB Waveforms, Scatterers are Coherently Summed into a Single RCS Response

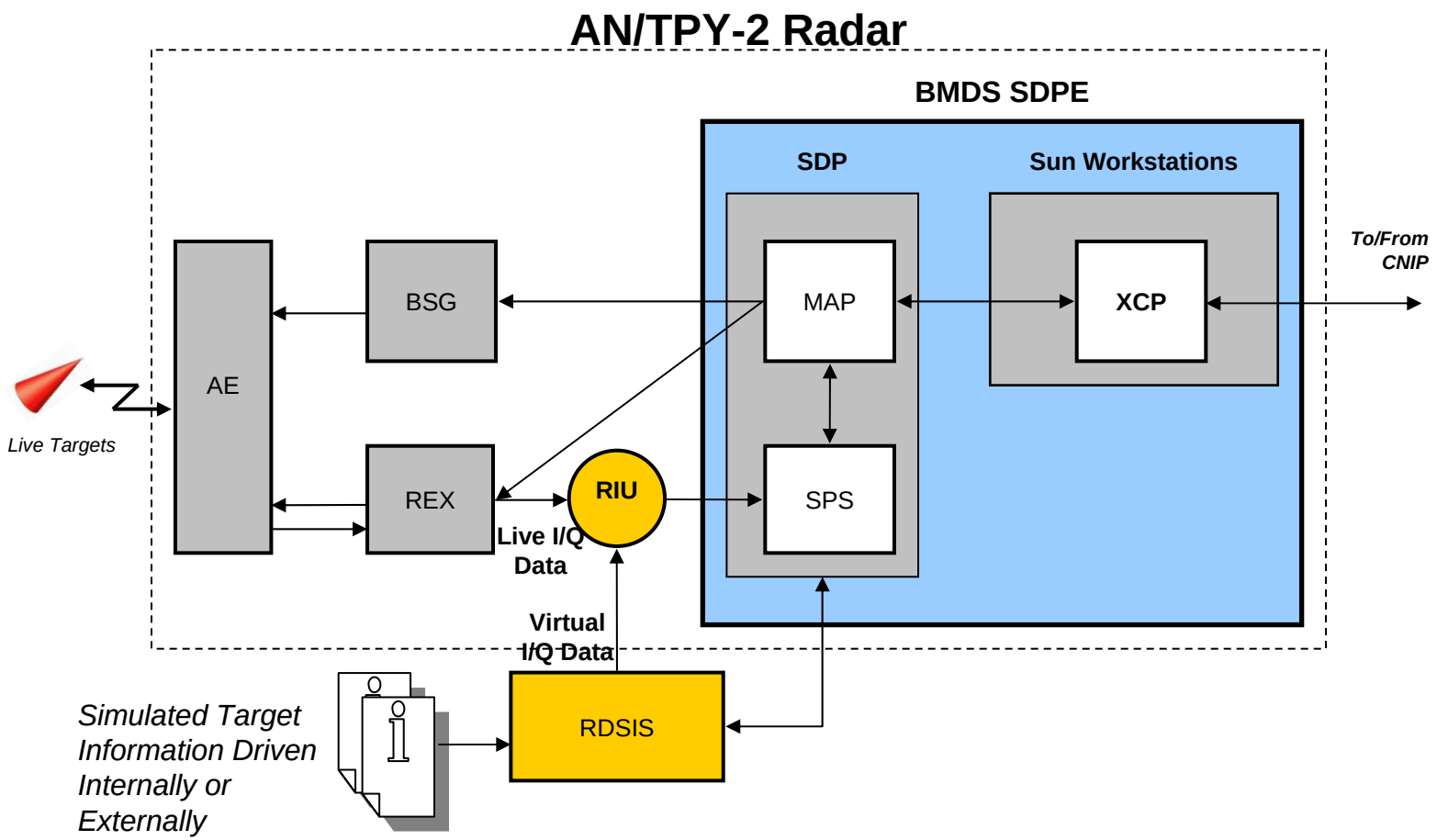
High Fidelity Stimulation Use Cases

The introduction of high fidelity stimulation into the AN/TPY-2 system test architecture has generated a wide range of Use Cases for this capability.

- **Discrimination Testing:** ***As the development of the BMDS matures, advanced techniques for target discrimination will make use of AN/TPY-2 data both at the organic sensor and in the system wide context.***
- **Software Development and Performance Evaluation:** ***The origin of RDSIS has been in the development of software for the AN/TPY-2 radar and will continue to play a vital role in this process. Additionally, standalone performance evaluations of the radar are possible to assess readiness of software builds and system performance.***
- **Ground Test:** ***The continued BMDS ground test campaigns will require multiple instantiations of the AN/TPY-2 radar to conduct system wide tests as more radars are integrated into the BMDS. High fidelity stimulation will enable more accurate system testing and evaluation.***
- **CTTO:** ***Concurrent Test, Training, and Operations applications will make use of high fidelity stimulation for system level testing and training to advance BMDS capabilities.***
- **VOL:** ***Realistic virtual-over-live testing is enabled by injection of complex scenes combined with live data to assess system performance in loading conditions.***
- **Deployable Stimulation:** ***Development of a deployable high fidelity stimulation for fielded radars provides on-site test capability and increases the fidelity of system ground test of fielded assets.***
- **SOLD:** ***The THAAD Sim-Over-Live-Driver (SOLD) utilizes RDSIS as a test asset.***
- **OTHER:** ***Continuing development of other and future X-band radars will implement RDSIS to meet development, test, and training needs. Examples: SBX and EMR***

Example Use Case Implementation: Virtual Over Live (VOL)

BMDS Radar / RDSIS Operating in a Virtual-over-Live Environment



Conclusion

- **Simulations are critical to the development and testing of the Ballistic Missile Defense System**
  - ***Critical to the development of algorithms such as discrimination methodologies***
- **High fidelity radar stimulation provides a needed capability to assess the readiness and performance of the AN/TPY-2 radar**
  - ***High fidelity target and environment signature modeling improves assessment capability***
  - ***Realtime execution capability is a key factor***
- **Application of high fidelity stimulation for the varied Use Cases will provide enhanced test and training thus improving the Warfighters capability**

Biographies

James A. Buford, Jr. - *Mr. James A. Buford, Jr. is Chief of the Strategic Defense Functional Area, System Simulation and Development Directorate of the U.S. Army Aviation and Missile Research, Development, and Engineering Center. He is also the Ballistic Missile Defense System (BMDS), Hardware-in-the-Loop (HWIL) Chief Engineer for the Missile Defense Agency (MDA) Modeling & Simulation Directorate (DESH). His primary role is as the technical and programmatic lead for the BMDS HWIL Test Framework Missile Defense Systems Exerciser (MDSE). MDSE provides the test framework for MDA's BMDS Ground Tests, Exercises, Training, and Continuous Test Training and Operations (CTTO) venues. Mr. Buford holds a Bachelor of Science degree in Electrical Engineering with a double minor in Mathematics and Computer engineering from the University of South Alabama and has completed an extensive array of graduate and professional development courses at the University of Alabama - Huntsville.*

James D. Coombs *- Mr. Coombs has over twenty years experience working with air and missile defense simulations, both digital and hardware-in-the-loop, at AMRDEC. He is currently the Chief of the Air and Missile Defense (AMD) Functional Area for AMRDEC's System Simulation and Development Directorate. His responsibility encompasses AMD simulations for multiple Army programs within the Lower Tier, Cruise Missile Defense, and Integrated AMD program offices. Mr. Coombs served as project lead for the PATRIOT Advanced Capability 3 (PAC-3) HWIL for 13 years. His HWIL experience encompasses testing of the HAWK, PATRIOT Multimode, and ERINT missiles. He is currently serving as the Technical Lead for Radar Stimulator development and integration within the BMDS MDSE Framework. Mr. Coombs holds a Bachelor of Science degree in Electrical Engineering (BSEE) from Tennessee Technological University in Cookeville, Tennessee.*

Anthony P. Rainoldi *- Mr. Rainoldi has two years experience of working with radar simulations at AMRDEC. He is currently leading the V&V effort for SLAMRAAM M&S in the Air and Missile Defense Functional Area for AMRDEC's System Simulation and Development Directorate. He has over six years experience with multiple radar systems, include various instrumentation radars, active protection systems, and the AN/TPY-2 radar. Mr. Rainoldi holds a Masters of Engineering (MSE) in Radar from the University of Alabama in Huntsville, Huntsville, AL, and a Bachelors of Electrical Engineering (BEE) Degree from Auburn University, Auburn, AL.*